

THE DISPOSAL BY BURIAL OF FRUIT INFESTED WITH LARVAE OF THE MEXICAN FRUIT FLY

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INTRODUCTION

The disposal of infested fruit and drops constitutes a major problem in a campaign of eradication or control waged against fruit flies. Such fruit is usually buried at specified depths for certain species of fruit flies. In most cases, however, there are few or no data to indicate how these depths were determined. In this circular the writers report the results of experiments carried on to show the depth that fruit infested with larvae of the Mexican fruit fly (*Anastrepha ludens* Loew) should be buried and how these depths were determined.¹

REVIEW OF RECENT EXPERIMENTS IN MEXICO

McPhail and Bliss ² showed that *Anastrepha ludens* adults emerged from depths as great as 18 inches when coarse, unpacked soil was used to cover infested fruit. The same writers found that twice as many adults emerged from six different depths (ranging from 1 to 18 inches) in the series of experiments protected from the sun as in a similar series exposed to the sun. Darby and McPhail ³ after conducting an experiment with puparia buried in three grades of soil—fine (x to 1 mm), medium (1 to 3 mm), and coarse (3 to 5 mm)—at depths of 4 and 6 inches, respectively, recorded that the best emergence was through fine soil when it was dry. However, in another similar experiment, using moistened soil and puparia buried at depths ranging from 4 to 12 inches, they observed that better emergence took place through medium and coarse soil than through fine soil.

¹ The experiments were conducted in cooperation with La Oficina Federal para la Defensa Agrícola, former office of the Secretaría de Agricultura y Fomento, México.

² MCPHAIL, M., and BLISS, C. I. OBSERVATIONS ON THE MEXICAN FRUIT FLY AND SOME RELATED SPECIES IN CUERNAVACA, MEXICO, IN 1928 AND 1929. U. S. Dept. Agr. Circ. 255, 24 pp., illus. 1933.

³ DARBY, H. H., and MCPHAIL, M. THE EFFECT OF BURIAL UPON THE EMERGENCE OF ANASTREPHA. 1929. (Unpublished report.)

It can readily be seen that various factors, such as moisture content, texture, and packing of the soil, have an important bearing on the proper depth fruit should be buried. Undoubtedly the different species of fruit flies vary considerably in their ability to overcome the same conditions imposed to prevent their emergence from the soil.

EXPERIMENT IN 1931

This experiment was conducted in Cuernavaca, Morelos, Mexico, in a location exposed to the sun. The experiment was divided into two series; one in which the surface of the soil was packed with a tamper, the other in which the soil was left unpacked. No trees bearing infested fruit were nearer than 200 feet to the plot. The work was done in the dry season when the soil was extremely dry and hard. Natives formerly made adobe bricks in part of the field where the plot was located. The soil was broken up as much as possible at the time the pits were dug. The fineness of the soil is shown in table 1.

TABLE 1.—Size of soil particles used in experiment in 1931 in burial of fruit infested with larvae of the Mexican fruit fly

Size of mesh of sieve		Weight of soil		Proportion of total weight	Size of mesh of sieve		Weight of soil		Proportion of total weight
Mm	Inches	Grams	Percent		Mm	Inches	Grams	Percent	
1	0.0394	3, 279	29.96		12	0.4724	2, 457	22.45	
3	.1181	1, 534	14.02		35	1.3779	2, 151	19.66	
5	.1968	1, 522	13.91		Total		10, 943	100.00	

The pits were dug and the piles of soil exposed to the sun several days before the fruit was buried. Each pit was approximately 2 feet square. The pits were so spaced that a wall of at least 12 inches of hard, dry adobe separated them. There was no possibility of larvae or adults from one pit becoming mixed with those of another. Seventy infested mangoes were placed in the bottom of each pit. The fruit was closely packed to simulate the condition that would exist at the top of the fruit buried in a large pit. The fruit was immediately covered after placing it in the pit. The soil was carefully shoveled into the pits, not scraped into them, from the sides. This prevented the larger pieces from accumulating in certain parts of the pits, as they would if the soil were scraped into them.

Eighteen pits were used in the experiment; 8 in the packed series, 8 in the unpacked series, and 2 controls. The depth at which fruit was buried was measured from the top of the fruit in the pits to the surface of the soil. Two additional inches were allowed for the space occupied by the single layer of mangoes in each pit. The pits in the unpacked series were 18, 22, 23, 26, 26.5, 27, 28, and 40 inches deep, respectively. Those in the packed series were 19, 22, 26, 27, 30, 33, 34, and 40 inches deep, respectively.

The soil of the pits in one series was packed with a light wooden tamper having a packing surface of 17 square inches. It weighed 11.5 pounds, most of the weight being at the tamping end. The packing was done by giving a single impact of the tamper to each part of the surface of a pit until the entire top was packed once. The soil of each pit sank approximately 1 inch, even though some of the pits were

twice as deep as others. Soil was added to fill the depression caused by the packing. It was packed a second time and leveled by adding more soil. The soil in the pits of the other series was left untouched.

Bottomless wooden cages 8 inches high covered with 18-mesh screen wire were used to cover the pits. The cages extended several inches beyond the edges of the pits. The larger size of the cages greatly reduced the amount of shade that fell on the surface of the soil.

The surface of the pits was examined daily during the period when there was a possibility of adult emergence. The coarse surface made the examinations for adults difficult because they would either die and fall between the particles or perhaps hide between them in an attempt to find protection from the sun. No live adults were found in any of the cages above the pits during the experiment. McPhail and Bliss,⁴ who carried on somewhat similar experiments with this insect, observed that "Some flies emerged even at the greatest depth of 18 inches, but all of these were so badly crippled that they died soon afterwards; . . ." Although all of the adults that emerged in the experiments were found dead, they appeared to be normal. The fact that they lived only a short time is attributed to exposure to the sun without food and water.

Darby and Kapp⁵ obtained the complete mortality of 50 adults of *Anastrepha ludens* at a cabinet temperature of 43.1° C. (109.5° F.) in less than 2 hours. Since temperatures as high as 52° C. (125.6° F.) were recorded at the surface of the pits as early as 11:30 a. m., it can readily be seen that adults would live only a very short time when unable to escape from such conditions.

After there was no possibility of further emergence of fruit flies from puparia, the soil of all the pits, with the exception of the 40-inch pit in the unpacked series and the 33- and 40-inch pits in the packed series, was carefully examined for adults, puparia, and parasites. The procedure was the progressive removal of 1-inch layers of soil from each of the pits until all had been removed. This soil was sifted through an 18-mesh screen sieve. Since only about 35 percent of the soil passed through such a sieve, the remainder had to be examined carefully to find the insect material. Probably many specimens were broken and lost by this method. Most of the soil in the unpacked series of pits had been sifted in this manner when the rainy season began, which precluded the further use of this method. The soil of the other pits was then examined by taking each 1-inch layer of soil and washing it through an 18-mesh sieve by means of a garden hose. Most of the soil passed through the sieve when this procedure was followed, leaving only coarse gravel in the sieve. This was dried and the insect material separated from it. In the unpacked series, the pits 18, 22, 23, and 26 inches deep, respectively, were sifted; also the first 14 inches of soil in the pit 27 inches in depth. The soil of the pits 19 and 22 inches in depth of the packed series was also sifted. The soil of all the other pits was washed.

In the examination of the soil it was found that the puparia were much easier to detect than the dried bodies of the adults. The latter were more easily destroyed in the sifting operations, and this partially accounts for the far greater number of puparia recovered. Only

⁴ McPHAIL, M., and BLISS, C. I. See footnote 2.

⁵ DARBY, H. H., and KAPP, E. M. OBSERVATIONS ON THE THERMAL DEATH POINTS OF *ANASTREPHA LUDENS* (LOEW). U. S. Dept. Agr. Tech. Bull. 400, 19 pp., illus. 1933.

complete specimens or thoraces of adults were recorded. The puparia were recorded as empty, full, malformed, caudal ends, cephalic ends, mid-sections, and fragments. The records of empty puparia are incorporated in the data as normal puparia from which adults emerged. The malformed, as well as the full puparia, are taken as those from which no adults emerged. The greater number of either caudal ends or mid-sections found at a given level is included in the number of puparia from which adults emerged. The total number and the condition in which they were found are shown in table 2.

TABLE 2.—*Summary of number and percentage of puparia from which no adult Mexican fruit flies emerged*

UNPACKED SERIES

Depth of pit (inches)	Total ¹	Normal ²		Malformed		Total full ³	
	Number	Number	Percent	Number	Percent	Number	Percent
18.-----	878	74	8.43	59	6.72	133	15.15
22.-----	678	13	1.92	15	2.21	28	4.13
23.-----	437	3	.68	11	2.52	14	3.20
26.-----	871	43	4.94	50	5.74	93	10.68
26.5.-----	381	0	0	8	2.09	8	2.09
27.-----	928	12	1.29	19	2.05	31	3.34
28.-----	380	1	.26	5	1.31	6	1.58
Total or average-----	4,553	146	3.20	167	3.66	313	6.87

PACKED SERIES

19.-----	813	37	4.55	68	8.36	105	12.91
22.-----	182	1	.55	3	1.65	4	2.20
26.-----	314	0	0	2	.64	2	.64
27.-----	468	1	.21	13	2.78	14	2.99
30.-----	253	7	2.77	1	.39	8	3.16
34.-----	576	0	0	20	3.47	20	3.47
Total or average-----	2,606	46	1.76	107	4.10	153	5.87

¹ All puparia, including normal (full), empty, and malformed, and those represented by caudal ends or mid-sections.

² Well-formed puparia from which no adults had emerged.

³ Includes only normal and malformed puparia.

The number of adults and puparia recovered from each pit in the two series, packed and unpacked, is shown in tables 3 and 4. The actual depth of burial is shown above the heavy cross rules, and the space occupied by the fruit is shown between the heavy cross rules. When all the soil of a pit had been removed the hard bottom was brushed to remove the loose soil. After this about an inch of hardpan was removed. The bottoms of the pits examined in the rainy season could not be brushed so well as the others, and the data shown for the inch of hardpan probably include some of the data that should be shown above it.

TABLE 3.—Numbers of *Anastrepha ludens* adults and puparia recovered in each pit in the unpacked series, 1931

Depth (inches)	Adults and puparia found in pits of depth specified 1													
	18 inches		22 inches		23 inches		26 inches		26.5 inches 2		27 inches		28 inches	
	Adults 3	Puparia	Adults	Puparia	Adults	Puparia	Adults	Puparia	Adults	Puparia	Adults 4	Puparia	Adults	Puparia
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
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26														
27														
28														
29														
30														
31														
32														
33														
Total	99	878	288	678	41	437	339	871	21	381	108	928	16	380

The lines between the heavy cross rules near the bottom of each column represent the 2-inch layer of mangoes in the bottom of the pit, and the line just below represents the

The lines between the nearly cross lines near the bottom of each column represent the Σ (mean) of mangos in the 100 pits. The layer of soil beneath the mangos. The depth of each layer in this pit was one-half inch less than would be implied by the position of the lines in this table.

⁴ 6 adults emerged.

46 adults emerged.

24 adults emerged.

TABLE 4.—Numbers of *Anastrepha ludens* adults and puparia recovered in each pit in the packed series

Depth (inches)	Adults and puparia found in pits of depth specified ¹											
	19 inches		22 inches		26 inches		27 inches		30 inches		34 inches	
	Adults	Puparia	Adults	Puparia	Adults	Puparia	Adults	Puparia	Adults	Puparia	Adults	Puparia
1												
2												
3												
4												
5												
6												
7												
8												
9												
10	2									1		
11	12											
12	17											
13	6											
14							1					
15	16	1	1									
16	50	10	1									
17	14	2	2									
18	40	18	13									
19	21	51	22	2			1					
20	8	133	5	3			2					
21	3	579	0	3	1		5					
22	0	19	1	14	1		1					
23			1	73	0		6					
24			0	86	0	1	8	1		1		
25			0	1	1	4	5	3				
26					0	32	2	10				
27					0	93	2	8		1		
28					2	166	8	110		5	1	
29					0	18	2	273		24	1	
30							2	63		3		2
31										67	1	
32										141	7	4
33										10	4	27
34											1	148
35											1	168
36											1	202
37											0	25
Total	189	813	46	182	5	314	45	468	0	253	18	576

¹ The lines between the heavy cross rules near the bottom of each column represent the 2-inch layer of mangoes in the bottom of the pit, and the line just below represents the 1-inch layer of soil beneath the mangoes.

No emergence of adults was recorded from pits in the packed series. In the unpacked series there was emergence from only two pits; 24 adults emerged from the 18-inch pit and 6 from the 27-inch pit. It seems strange that no adults came through the soil in the pits that were 22, 23, 26, and 26.5 inches, in depth, but emerged from the greater depth of 27 inches. The fruit in the control pits was buried 6 inches but it was completely destroyed by ants. The ants, however, did not disturb the fruit in the other pits.

It will be noted that the greatest number of larvae pupated in the soil surrounding the fruit at the bottom of the pits (tables 3, 4, and 5). Nearly 78 percent of the larvae in the unpacked series and over 80 percent of those in the packed series pupated at that point. Above this level the number of larvae pupating in the soil decreased rapidly, only 10.2 percent having pupated in the first inch of soil above the fruit in the unpacked series and 9.8 percent in the packed series. At the 2-inch level above the fruit 4.7 percent of the total puparia were

found in the unpacked series and 3.3 percent in the packed series. Approximately 5 percent of the puparia were found in the inch of soil taken from the hard bottoms of the pits of both series.

TABLE 5.—*Number and percentages of Mexican fruit fly puparia recovered in the same layers of all pits of the packed and unpacked series*¹

Position of layer (distance in inches above fruit)	Unpacked series (7 pits)		Packed series (6 pits)		Position of layer (distance in inches above fruit)	Unpacked series (7 pits)		Packed series (6 pits)	
	Pupa- ria recov- ered	Pro- por- tion of total	Pupa- ria recov- ered	Pro- por- tion of total		Pupa- ria recov- ered	Pro- por- tion of total	Pupa- ria recov- ered	Pro- por- tion of total
	Num- ber	Per- cent	Num- ber	Per- cent		Num- ber	Per- cent	Num- ber	Per- cent
22-----	1	0.02			2-----	215	4.72	86	3.30
21-----			1	0.04	1-----	463	10.17	256	9.82
16-----	1	.02			2-inch space occupied by fruit-----	3,545	77.86	2,091	80.24
8-----	1	.02			1 inch below bottom of pit-----	211	4.63	136	5.22
7-----	7	.15	1	.04	Total-----	4,553	100.00	2,606	100.00
6-----	12	.26							
5-----	15	.33	3	.12					
4-----	29	.64	14	.54					
3-----	53	1.16	18	.69					

¹ Puparia include those that were empty and full; also those represented by caudal ends or mid-sections; in the latter case the greater number of either one is included.

The tendency of some larvae to travel considerable distances from the fruit toward the surface of the soil before pupating is illustrated by the recovery of a puparium 22 inches above the fruit in a pit containing 27 inches of unpacked soil; another at 16 inches above in a pit containing 26 inches of unpacked soil, and a third at 8 inches above in a pit containing only 18 inches of soil above the mangoes (table 5). It is significant that flies emerged from the first and third of these pits. That means the flies had to travel at least 5 inches in the first instance and 10 inches in the second instance, if any emerged from those puparia found close to the surface. In the packed series of pits one puparium was found 21 inches and another 7 inches above the fruit, both in the 30-inch pit. All the other puparia in this series were recovered at 5 inches or less above the level of the fruit.

The total number of adults recovered from both series was very small; only 972, or 22.92 percent, of those represented by empty puparia were found in the unpacked series, and 303, or 12.35 percent, in the packed series (tables 6 and 7). The difference in the percentages is probably due to the fact that the soil of most of the pits of the packed series had to be washed. More adult material was probably lost by this method than by sifting the soil. The number of adults recovered, however, should give an indication of the effect of packing the soil in this series. Very few adults were recovered from the soil around the fruit. Of the total number of adults found in the unpacked series of pits, 74.1 percent were within 7 inches of soil above the fruit, 54 percent being in the 4 layers from 4 to 7 inches, inclusive, above the fruit. These data are to be compared with those of the packed series, in which 78.9 percent of the flies were in the first 7 inches of soil and 44.9 percent in the layers 4 to 7 inches above the fruit. There was a good recovery of adults in the unpacked series

from soil 10 to 15 inches above the fruit, but only 1 adult was recovered above the 10-inch level in the packed series. The packing of the soil undoubtedly had something to do with the failure to find adults at higher levels. The number of adults found in all the pits, compared with the number of puparia collected, is shown in table 7.

TABLE 6.—Number and percentages of adults recovered in the same layers of all pits of the packed and unpacked series

Position of layer (distance in inches above fruit)	Unpacked series (7 pits)		Packed series (6 pits)		Position of layer (distance in inches above fruit)	Unpacked series (7 pits)		Packed series (6 pits)	
	Adults recov- ered	Pro- por- tion of total	Adults recov- ered	Pro- por- tion of total		Adults recov- ered	Pro- por- tion of total	Adults recov- ered	Pro- por- tion of total
	Num- ber	Per- cent	Num- ber	Per- cent		Num- ber	Per- cent	Num- ber	Per- cent
15-----	3	0.31			4-----	177	18.21	81	26.73
14-----	23	2.37	1	0.33	3-----	87	8.95	31	10.23
13-----	28	2.88	0	.00	2-----	64	6.58	47	15.51
12-----	20	2.06	0	.00	1-----	44	4.53	25	8.25
11-----	24	2.47	0	.00	2-inch space occu- pied by fruit	26	2.67	26	8.58
10-----	26	2.67	2	.66					
9-----	40	4.11	13	4.29	Total-----	972	100.00	303	100.00
8-----	62	6.38	20	6.60					
7-----	91	9.36	13	4.29					
6-----	105	10.80	5	1.65					
5-----	152	15.64	37	12.21					

TABLE 7.—Summary of number of adults and empty puparia recovered from both series of burial pits

Unpacked series								Packed series			
Depth of pit (inches)	Empty puparia	Adults emerged		Adults from soil		Total adults		Depth of pit (inches)	Empty puparia	Total adults ¹	
		Number	Percent	Number	Percent	Number	Percent			Number	Percent
18-----	745	24	3.22	99	13.28	123	16.50	19-----	708	189	26.69
22-----	650	0	0	288	44.30	288	44.30	22-----	178	46	25.84
23-----	423	0	0	41	9.69	41	9.69	26-----	312	5	1.60
26-----	778	0	0	339	43.57	339	43.57	27-----	454	45	9.91
26.5-----	373	0	0	21	5.63	21	5.63	30-----	245	0	0
27-----	897	6	.66	168	18.73	174	19.39	34-----	556	18	3.23
28-----	374	0	0	16	4.27	16	4.27				
Total or average--	4,240	30	.70	972	22.92	1,002	23.63	Total or average--	2,453	303	12.35

¹ All from soil.

The presence of pupal parasites caused a slight error in computing the number of adults that might be obtained from the puparia found in the pits. This error is negligible because the proportion parasitized was less than 1 percent at the time this work was started. It will be noted that six specimens of the parasite *Opius crawfordi* Vier. were found in the unpacked series of pits and none in the packed series (tables 3 and 4). One of the adults was found 18 inches above the fruit and 14 inches above the nearest puparium; another was found 16 inches above the fruit and 11 inches above the nearest puparium.

DISCUSSION

The depth at which fruit must be buried to prevent the emergence of adults from unpacked, dry soil cannot be determined by taking the pit of greatest depth from which no adults emerged and declaring that to be the proper depth for the burial of infested fruit, unless there is a larger number of pits in the experiment than the one reported here. The records of the location of the insect material in the soil are especially valuable for this reason. The 27-inch pit of the unpacked series can be taken as an example. Six adults emerged from this pit and only one puparium was found beyond the 7-inch level above the fruit (table 3). This puparium was at the 22-inch level above the fruit, or within 6 inches from the surface of the soil. Only 1 of the 6 adults that emerged from this pit could have come from the puparium found at the highest level. Since the puparia next nearest to the surface were found at the 7-inch level above the fruit, some of the adults must have passed through at least 20 inches of soil in order to reach the surface. If the distance traversed by the larva which pupated in the level 22 inches above the fruit is added to the distance that some of the adults must have traversed (20 inches), the total is 42 inches. As several inches should be added as a factor of safety, the minimum depth at which fruit should be buried in dry, unpacked soil of this type would be 4 feet.

The depth at which fruit should be buried in pits when the surface is packed to some extent with a tamping implement can be computed as for the unpacked pits by taking the highest levels at which adults and puparia are found above the level of the fruit and adding the inches of soil through which the larvae and adults passed. However, the factor of packing enters into consideration and, as later experiments show, the effect is greater near the surface and extends to about the same depth in all the pits. This is shown by the fact that when the soil was packed the surface of all the pits sank approximately the same distance. The highest level at which a puparium was found in this series was 21 inches above the level of fruit (30-inch pit), and the highest level at which an adult was found was 14 inches above the fruit and 10 inches above the nearest puparium (27-inch pit). Thus larvae and adults passed through at least 31 inches of soil. That no emergence was obtained from the packed series, despite the fact that some of the larvae and adults traveled a considerable distance toward the surface of the pits, can only be attributed to the packing, since all other factors were nearly equal. Until further experimentation, it can be determined from the data that burial under 18 inches of dry, well-packed soil will be sufficient to prevent the emergence of *Anastrepha ludens* from burial pits. As a further precaution several more inches of soil might be added.

An observation indicates that May beetle grubs or adults (*Phyllophaga* spp.) and such insects as the emerging nymphs of cicadas may open passageways in the soil through which larvae emerging from buried fruit and adults emerging from puparia might escape. Six pits were empty at the time the observation was made. On the sides of each of these pits the emergence holes of May beetles were found. Some of the beetles were trapped in the empty pits that were covered with cages. One beetle was found dead in one of the emergence holes in the side of the pit. There were 39 emergence holes in the six pits,

16¼ inches being the maximum depth at which one was found. The surface of the soil of those pits that had not been dug at the time this observation was made was carefully examined. No emergence holes were noted except at the edges of the pits where fissures in the soil had opened. It is improbable that there were any beetle pupae below the bottoms of the pits.

After the period when there was any possibility of adults of *Anastrepha ludens* emerging from the soil of the pits, it was observed that irregular cracks or fissures opened around the edges of the pits when a few hot, dry days followed a rainfall sufficient to moisten the soil to a depth of several inches. Upon measuring the fissures of two pits of each series, they were found to have maximum depths ranging from 2¾ to 4⅞ inches and maximum widths ranging from three-sixteenths to seven-sixteenths inch.

Since fissures may open at the edges of the pits and burrowing insects may open passageways that might enable *Anastrepha ludens* adults to escape from the soil, it is recommended that burial pits be examined occasionally to make sure that there is no possibility of adult emergence through such fissures or passageways.

EXPERIMENT IN 1932

The results of the 1931 experiment showed that the packing of the soil in which infested fruit was buried was of considerable importance. For that reason all the sand used in the newly dug pits the following year was packed in order to procure more data on this factor.

In this experiment 4 pits filled with packed dry sand and 4 pits filled with packed moist sand were used. The sand was thoroughly dried by spreading it on a tarpaulin. It was uniformly moistened, care being taken not to add too much water. When moistened, the sand was not flocculated. The pits of the two series were arranged alternately. They were covered with the cages used in the previous experiment.

The eight pits were all dug some time previous to the start of the experiment, close to those made the previous year. They were of the same size, 2 by 2 feet, and about 20 inches deep. The measurements were made from the bottom upward because some of the pits were made slightly deeper when the bottoms were leveled. To accomplish this with accuracy a 1- by 2-inch stake was placed about 2 inches out from one wall of each pit. The stake was marked at 2 inches and at 20 inches. Thus when sand was placed in the pit, the top was 20 inches from the bottom or 18 inches from the top of the mangoes. The tamper used the previous year was used again, but it was too large to pack the sand in the immediate vicinity of the stake. This source of error was eliminated by tightly packing the sand every few inches around the stakes with a small piece of wood when the pits were being filled.

The fine river sand used in this experiment was first sifted to remove any foreign material that might have been present. The sifting of a sample weighing 345.4 grams showed that 77.8 percent varied from x to 0.5 mm, 15.7 percent from 0.5 to 1.0 mm, and 6.4 percent from 1.0 to 2.0 mm in size.

One hundred mangoes that appeared to be well infested were placed in a single layer at the bottom of each pit. These layers lacked but little of being 2 inches in depth. Care was taken to make sure that

the mangoes were well spaced and that those in the outer rows actually touched the sides of the pits. The first mangoes were buried March 7, 1932. The next operation was to fill the pit with either dry or moist sand until the 20-inch level on the stake was reached. The entire surface of the sand was then well packed. After this packing, more sand was added until the 20-inch level was again reached. Packing with the tamper was then repeated. After the second packing, sand was added up to the 20-inch level on the stake, but was not packed again. The effect of this packing is shown in table 8.

TABLE 8.—*Depression of the sand of the burial pits caused by packing with a wooden tamper*

Dry series				Moist series			
Pit no.	First packing	Second packing	Total	Pit no.	First packing	Second packing	Total
	Inches	Inches	Inches		Inches	Inches	Inches
2.....	2 $\frac{7}{16}$	1 $\frac{1}{4}$	3 $\frac{1}{16}$	1.....	4 $\frac{3}{8}$	2 $\frac{5}{16}$	6 $\frac{1}{16}$
4.....	2 $\frac{5}{16}$	1	3 $\frac{5}{16}$	3.....	4 $\frac{1}{8}$	2	6 $\frac{1}{8}$
6.....	3 $\frac{1}{4}$	1 $\frac{1}{8}$	4 $\frac{3}{8}$	5.....	5 $\frac{1}{16}$	2 $\frac{1}{2}$	7 $\frac{13}{16}$
8.....	2	1	3	7.....	6	2 $\frac{7}{8}$	8 $\frac{7}{8}$

Soil temperatures were recorded among the mangoes at the 20-inch level of pit no. 6 from March 29 to May 15, 1932, inclusive. During this time the temperature was very constant, ranging between 28° and 31° C. (82.4° and 87.8° F.). The daily mean air temperatures taken in the shade for this period (except Apr. 11, 12, and 13) ranged from 20.5° to 29° C. (68.9° to 84.2° F.),⁶ the mean for the 45 days being 25.8° C. (78.4° F.).

The examination of the surface of the pits was greatly facilitated by the sand and the white sides of the cages placed above the pits. No adults emerged from any of the pits. When all chance of adults emerging had passed, the dry-packed sand was removed in 1-inch layers and sifted through an 18-mesh sieve. Nearly all the sand passed through the sieve, leaving mostly insect material which could be removed and examined very easily. The sand that had been moistened became very hard upon packing and standing. It could be removed only in large pieces which could be broken with difficulty. For this reason the sand in only one of the pits of this series was removed and examined. The small amount of insect material recovered indicates that probably much of it was destroyed and lost when the chunks of sand were broken. It is inconceivable that the flies could move any distance through sand so compact and solid.

A summary of the material obtained by sifting the sand is shown in table 9. A total of 596 flies, or 46.4 percent of those that emerged, if based on the total of 1,284 empty puparia, were recovered from the four pits that contained dry sand. Only 6 flies, or 3.6 percent, out of a possible 163 flies, were recovered from the single pit examined of those containing moist sand. Only 1 fly was found as high as 9 inches above the fruit, but 1 dead larva was found 11 inches above the fruit in one of the pits. It will be noted that the great majority of the flies were found within the 4 inches of sand above the fruit as well as the

⁶ Summarized from 2-hour readings taken from the thermograph.

sand around the mangoes at the bottom of the pits. In the dry sand 1 puparium was 6 inches above the fruit; 476 puparia were in the first 4 inches of sand and 1,106 (nearly 70 percent) in the space occupied by the mangoes.

TABLE 9.—Numbers of *Anastrepha ludens* adults and puparia recovered from specified depths of sand in pits, 1932

Depth (inches)	Adults					Puparia ¹												
	Wet sand	Dry sand					Wet sand		Dry sand									
		Pit 1	Pit 2	Pit 4	Pit 6	Pit 8	Pit no. 1		Pit no. 2		Pit no. 4		Pit no. 6		Pit no. 8			
							Total	Empty	Total	Empty	Total	Empty	Total	Empty	Total	Empty		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8					(2)													
9																		
10			1	(2)	(3)													
11			1	(2)														
12			3		4													
13			2	1	11					1								
14			7	7	14													
15			21	12	26	2				5	5	1	1					
16			25	28	22	26	4	2	11	8	2				3			
17		2	42	38	32	12	7	7	74	47	12	8	8		6	6	1	2
18			44	46	44	29	19	15	176	146	45	38	67	50	71	60		
19		4																
20			15	33	42	6	157	139	319	260	262	214	304	240	221	197		
Total		6	161	165	195	75	187	163	586	466	322	261	380	297	295	260		

¹ Total puparia include empty puparia and those from which no adults emerged; empty puparia include also caudal ends or mid-sections, the larger number being taken.

² 1 dead larva.

³ 2 dead larvae.

⁴ This 2-inch layer was occupied by mangoes.

DISCUSSION

The experiment clearly shows that 18 inches of well-packed sand, either wet or dry, placed above the fruit is sufficient to prevent the emergence of *Anastrepha ludens* adults. Moistened sand, when packed, becomes hard and caked and for this reason appears more satisfactory than packed, dry sand. It is probable that fruit would not have to be buried so deep if moist sand were used, but more data will be needed before a shallower depth can be recommended.

It should be noted that all these experiments were carried on with mangoes, primarily because they were available at a time in the dry season most suitable for carrying on field experiments. It would have been much better if well-infested citrus fruit had been available. While no comparative data are available, it is believed that these results will hold for citrus as well as mangoes.

In the summer of 1931 the writers had the opportunity to observe what takes place when large numbers of mangoes are piled together and covered with 6 to 8 inches of soil. Many of these mounds were broken up late in the season in a search for living larvae and puparia

It was noted that many full-grown larvae had been killed. It is thought that this was the result of fermentation processes that took place in the fruit. No similar observations were made in the depth-of-burial studies, in which very few dead larvae were found.

PACKING EXPERIMENT

In the experiment of 1931 it was noted that the soil sank approximately 1 inch when packed, irrespective of the depth of the pit. The

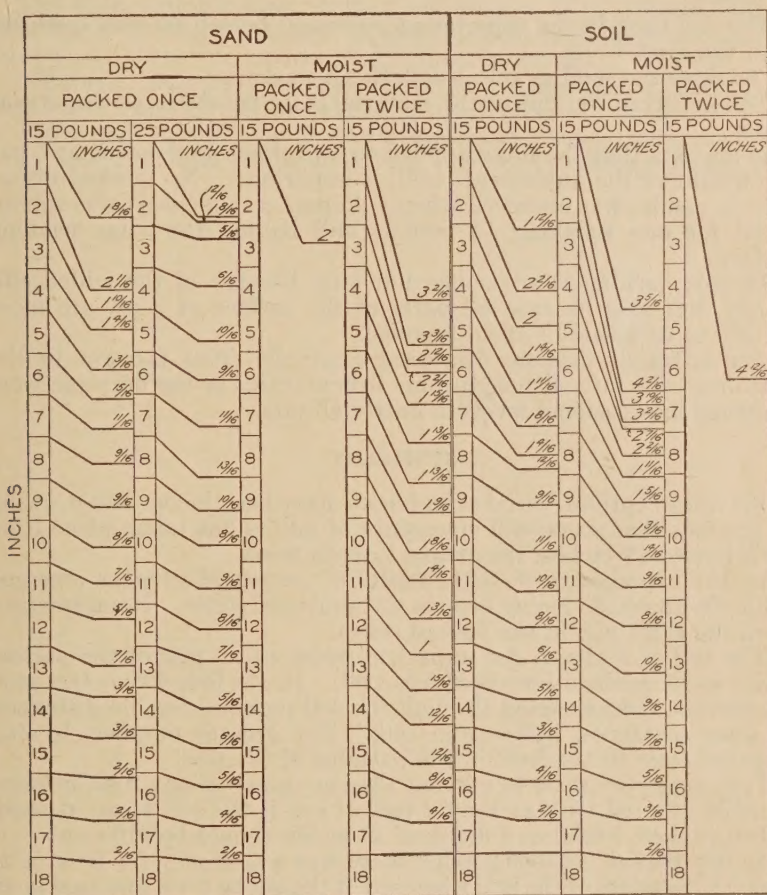


FIGURE 1.—Effect of packing (with 15- or with 25-pound implements) on successive 1-inch layers of screened sand and soil in pits. In each diagram the positions of the 1-inch layers in the pit before packing are represented by transverse lines at the left; these are connected with transverse lines at the right representing the positions of the same layers after packing, with figures showing the distance (in inches) that each layer was depressed.

experiment of 1932 clearly indicated that packed moist sand was superior to packed dry sand as a covering for infested fruits buried in pits.

Packing appeared to be such an important factor in preventing fruit fly adults from emerging from the burial pits that experiments were carried on in Mexico City in 1933 to learn more about the effects

of packing under various conditions. The special technic employed and the results of these experiments have been summarized by Stone.⁷ In the part of the experiment reported here, alluvial sand (similar to that used in the 1932 experiment) and common soil of the locality were used. Both were screened to eliminate foreign material and large lumps. The results of part of the experiment are shown in figure 1.

From the results of this experiment the following conclusions can be drawn:

The soil used in the experiment possessed better packing qualities than the sand.

The finer the sand or soil, the better it packs.

The moisture content of the material is by far the most important factor.

It appears that the force applied to a packing implement, and not the weight of the implement itself, is important. No marked difference in results was observed when a 25-pound implement was substituted for one weighing 15 pounds and having the same packing surface.

Double packing is advisable, not only because of the added efficiency, but also because all parts of the surface of a pit are more certain to be treated in field practice.

The effect of packing decreased gradually from the top to the bottom of the pits, although some irregularities in the decrease were observed in occasional levels in nearly all pits.

SUMMARY

Previous depth-of-burial experiments have been inconclusive, owing to the fact that successful emergence of adults has taken place from fruit buried 18 inches, the greatest depth tried.

In the experiment of 1931, adults of *Anastrepha ludens* emerged from pits 18 and 27 inches deep in the unpacked series. None emerged from the eight pits in the packed series.

The soil of 7 pits of the unpacked series and 6 pits of the packed series was examined for insect material. It was found that larvae of *Anastrepha ludens* passed through the soil for considerable distances, in some instances, before pupating. The greater number, by far, pupated close to the fruit in the bottoms of the pits.

It is suggested that, to prevent the emergence of any flies, infested fruit be covered with at least 4 feet of soil if the soil is not packed. When packed, burial at a depth of 18 inches should be sufficient.

In dry periods following rains there was a tendency for fissures to open at the edges of the pits when soil of the adobe type was used in an experiment.

Burrowing insects make passages in the soil through which fruit fly adults might escape.

Burial pits should be examined occasionally to make sure that no flies are being allowed to escape through fissures that are formed in the soil or by passages made by other insects.

In the experiment of 1932 no adults emerged from 18 inches of packed wet and dry sand placed above infested fruit. One dead larva

⁷ STONE, W. E. COMPARATIVE EFFICIENCY OF SINGLE AND DOUBLE PACKING WITH 15 AND 25 POUND PACKERS ON SCREENED AND UNSCREENED, WET AND DRY SAND AND SOIL IN FRUIT-DISPOSAL PITS. 1934. (Unpublished report.)

was found as high as 11 inches above the fruit. Most of the puparia were in the soil surrounding the fruit; one was 6 inches above the fruit; the rest were within 4 inches above the fruit. One adult was found 9 inches above the level of the fruit, but most of the adults were within the first 4 inches.

When moistened the sand becomes so compact and hard that it is inconceivable that flies could pass through it.

The data indicate that no flies will emerge from infested fruit if it is covered with 18 inches of well-packed, preferably moistened, sand when it is as fine as that used in this experiment.

Although mangoes were used in these experiments, it is believed that these results will also hold for citrus fruits.

The conclusions derived from an experiment to determine the effect of packing the surface of sand and soil in pits 18 inches deep are given.

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